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Feasibility Analysis of Quary Tapinalu Material as Asphalt Concrete-Base Mixed Aggregate in Road Works

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ABSTRACT

Quary Tapinalu is a quarry located in the western part of the Seram district. The material taken from the Wai Tapinalu river is the first time it has been used for Road Structure Capacity Enhancement work. In this study, material feasibility tests will be carried out in the form of 5-10 broken stones, 10-20 broken stones and 20-30 broken stones, sand and stone ash. This research was conducted at the Asphalt Laboratory, Department of Civil Engineering, Ambon State Polytechnic. With reference to the Highway Specification, Revision 2018 2. The data analysis carried out in this study includes abrasion, specific gravity and absorption of coarse and fine aggregates, moisture content, sludge content, sieve analysis and marshall test. Based on the results of testing in the laboratory, abrasion values of 33.38% were obtained, the specific gravity and absorption of coarse aggregates consisting of bulk specific gravity of 2.70, SSD specific gravity of 2.73, apparent specific gravity of 2.78, and absorption of 1.21%, specific gravity and absorption of fine aggregate consisting of bulk specific gravity of 2.53, specific gravity of SSD 2.57, apparent specific gravity of 2.62 and absorption of 1.40%, The proportion of 10-20 mm broken stone is 20%, 20-30mm broken stone is 21%, 5-10mm broken stone is 18%, sand is 12%, and ash is 28%. Marshall's characteristics at the optimal level are 5.5%. From the results of Marshall's analysis on KAO, it was obtained that the VIM value was 4.29%, VMA 15.72%, VFB 72.69%, Flow 3.25 mm, Stability 1866 kg/mm and Marshall Quotient 450.00 kg/mm.

1. INTRODUCTION

Quary Tapinalu is located in the Western Seram Regency, precisely in Tapinalu Village, Huamual District. The material in this quarry is used for the first time for work to increase the capacity of road structures. Utilization of materials on the Wai Tapinalu River. With rainfall that continues to increase, so that materials carried by the current can be renewed after use. The total material availability is 180,000 m$\pm^3$. The material from the Tapinalu River consists of large, irregular, flat and oval rocks, as well as fine aggregates that are free from clay clumps and have a rough surface. Through the process of breaking stones by stone breaking tools, coarse and fine aggregates are obtained, namely 20-30 broken stone, 10-20 broken stone and 5-10 broken stone, sand, stone ash and 60-70 asphalt. This material is used in the project to increase the capacity of the Limboro-Ulatu Hamlet road structure. For this reason, the quality of aggregate for pavement materials must meet the specifications of Bina Marga, Revision II, Division 6. Asphalt Pavement (2018).

Based on the explanation above, the background for testing the material of the Wai Tapinalu River as a mixture of fine aggregate and coarse aggregate in the form of 20-30 crushed stone, 10-20 crushed stone and 5-10 crushed stone, sand, stone ash as well as flattening and sloping coarse aggregate material. It will be known that the material taken from Quary Tapinalu is suitable for use for the AC-Base mixture later in road construction work.

Figure 1. Quary Tapinalu

2. Literature Review

2.1 Road Pavement Construction

Flexible Pavement Construction is a pavement that uses asphalt as a binding material. The pavement layer is to bear and distribute the traffic load to the ground floor. Road pavement, both flexible pavement and flexible pavement, has a structural and functional function. A pavement layer is said to have a structural function of a flexible pavement arrangement consisting of:

1) Surface course
2) Top Foundation Layer (base course)
3) Bottom foundation layer (sub base course)
4) Subgrade

2.2 Materials that make up the road pavement

a. Coarse Aggregate

Gravel or crushed stone obtained from the stone breaking industry is an example of coarse aggregate, which has a grain size between 4.75 mm and 5.25 mm (No.4) up to 40 mm 112 inches due to the stability of the asphalt aggregate mixture obtained from the interlocking of the aggregate, the coarse aggregate plays an important role in the formation of performance.

b. Fine Aggregate

Aggregates with a maximum grain size of 4.74 mm are known as fine aggregates. Fine aggregates derived from source material or sand or sifted crushed stone material that meets No. 8 (or 2.36 mm) and filter No.200 (0.075 mm) and must be free of clay, hard, and clean soil.

c. *Filler*

Concrete asphalt mixture contains *filler* of a material by passing the filter No.200 (0.075mm). Stone ash, lime, portland cement, or other materials can compose the filler material itself.

d. Asphalt

Asphalt is a material that is black and dark brown in color and functions as a binding material, at the temperature of the room in a solid to slightly dense shape. Most of them are formed from *hydrocarbon* elements called *Bitumen*, so asphalt is often also called *Bitumenous Material.* Asphalt is the product of natural materials, so the properties of asphalt must always be checked in the laboratory and asphalt that meets the requirements that have been determined can be used as a binding material for flexible road pavements.

2.3 Asphalt Concrete – Base (AC-Base)

Asphalt concrete (*Asphalth Concrete*) in Indonesia is known by other names Laston (Asphalt Concrete Layer) is a layer in highway construction, which consists of a mixture of hard asphalt and aggregate that is graded, mixed, laid and compacted in a hot state at a certain temperature. Generally used for roads with heavy traffic, the most important characteristic in the mixture is stability. The minimum thickness of the laston is 4-6 cm. Laston as the foundation layer, known as AC-Base). The upper laston or foundation layer (AC-Base) is a pavement foundation consisting of a mixture of aggregate and asphalt with a certain ratio mixed and compacted in a hot state. The foundation layer (AC-Base) has the following functions: providing surface layer support, reducing strain and stress, spreading and passing on the road construction load underneath it and is a pavement layer located under the fastening layer (AC-BC).

2.4 Flatness and Coarse Aggregate Flatness

The strength and durability of a road pavement construction is highly dependent on the quality of the aggregate and the type of asphalt used as the main material to bind these materials until a pavement that is durable, durable, strong and abrasive is obtained.

2.5 Mixed Planning

Mixture planning aims to obtain a mixture from the materials contained at the work site so as to produce a mixture that meets the specified mixture specifications. Currently, the most widely used mixed design method in Indonesia is the mixed design method based on empirical testing, using Marshall tools. Before the production of asphalt mixture is carried out, it is necessary to make a composition of the working mixture or *Desing mix formula* obtained from the results of experiments in the laboratory. The first step of planning this work mixture is to test the quality of materials, both agragat and asphalt.

The next step is to carry out calculations and experiments on the composition of the mixture in the laboratory and finally to evaluate the characteristics of the mixture with a series of *Marshall tests* from the prepared samples. Planning the composition of asphalt mixtures is stability, durability, flexibility, and shear resistance. The expected mixture is a mixture that meets the specifications and achieves the optimum asphalt rate, in relation to the properties/conditions of the asphalt mixture according to the type of pavement layer.

2.6 Test Methods

a. Aggregate Sieve Analysis

Testing Method Analysis of fine and coarse aggregate sieves using a sieve This technique is used to determine the grain division (gradation) of fine aggregate and coarse aggregate using a size distribution or the number of grain percentages. The percentage of aggregate grains that pass through a set of sieves is then displayed on a grain division graph is what is known as aggregate sieve analysis**.** Calculation formula:

Cumulative held = cumulative held + weight held (1)
Total retained percent = cumulative retained x 100% (2)
Percent pass = 100 - % total (3)

b. Specific Gravity and Aggregate Absorption

This examination aims to find out the specific gravity of the aggregate and the ability to absorb water.

Dry specific gravity $Sd = \frac{A}{(B-C)}$ (4)

Pseudospecific gravity $Sa = \frac{A}{(A-C)}$ (5)

Water absorption $Sw = [\frac{B-A}{A} x 100\%]$ (6)

c. Aggregate Wear Testing (*Abrassion)*

This inspection aims to determine the resistance of the coarse aggregate to wear by using the los angeles machine. The wear is expressed by the comparison between the weight of the wear material through the No.12 sieve to the original weight, in percent (%).

$$\text{Wear}= (7)\frac{a-b}{a}\ x\ 100$$

d. Aggregate Shape Analysis/Aggregate Flatness Index

This check is intended to determine the flatness index of the coarse aggregate. Flattened aggregate particles can be the result of a stone crushing machine or indeed a property of the aggregate which if broken tends to be flattened.

$$\text{Flatness Index F} = \frac{(p_1\, x\, f_1 + p_2 x\, f_2 + \cdots + p_n\, x\, fn)}{p_t} \quad (8)$$

$$\text{Index E} = \frac{(p_1 \times e_1 + p_2 \times e_2 + \cdots + p_n \times e_n)}{P_t} \quad (9)$$

Flat Aggregate Granules and Oval Aggregate Granules

$$\text{E} = \frac{(p_2 \times fe_1 + p_2 \times fe_2 + \cdots + p_n \times fe_n)}{p_t} \quad (10)$$

e. Stability

In kilograms, stability refers to the ability of a hard layer to withstand traffic loads without undergoing permanent deformation. The value on the clock hand serves as the basis for calculating the stability value. The read value is used as the basis for calculating the stability value. The value read on the watch must be converted to the marshall scale for stability value.

f. Fatigue (*Flow*)

The fatigue reading on the marshall instrument shows the flow value. The value is obtained from the watch the flow reading in millimeters, so conversion is not necessary.

g. Marshall Quotient

The Mashall Quotient can be calculated using the following equation formula:

$$\text{MQ} = \frac{MS}{MF} \quad (11)$$

h. Cavities in the mixture (VIM)

The deep air cavity (VIM) in the asphalt pavement mixture consists of the space between the aggregate particles that are covered in asphalt. The volume of the air cavity in the mixture can be determined by the following formula:

$$\text{VIM} = 100 - \frac{100x\ Berst\ Volume\ \ B.U}{B.J.Max\ teoritis} \quad (12)$$

i. Cavity in aggregate (VMA)

The cavity between aggregate minerals (VMA) is the cavity between the aggregate particles on a pavement, including the air cavity and the effective volume of asphalt (excluding the volume of asphalt absorbed by the aggregate.

$$\text{VMA} = 100 - \frac{[\{Gmb\ x\ Ps)]}{Gsb} \quad (13)$$

j. Asphalt filled cavity (VFB)

The cavity filled with asphalt or the volume ofids fillet with asphalt (VFB) is the percentage of cavities that exist between aggregate particles (VMA) filled by asphalt, excluding asphalt absorbed by aggregate. The formula is as follows:

$$\text{VFB} = 100x\,\frac{(VMA-VIM)}{VMA} \quad (14)$$

3 METHODOLOGY

3.4 Research Location

The research is located in Quary Tapinalu, Tapinalu Village, West Seram Regency as the location of material collection as shown in Figure 2.

Figure 2. Research Location
https://earth.google.com/earth/d/1Sj9tQIgBfN6fe-PCgMbu_iYhvQ7qM8lf

3.5 Data Collection and Analysis

In general, the research methods carried out include the identification of problems and objectives, literature studies, the data collected is divided into: (1) primary data, namely testing data from testing in the laboratory of the Department of Civil Engineering, Ambon State Polytechnic, and (2) secondary data, namely Job Mix Design data and Indonesian National Standards. The data collection technique is carried out using the experimental method, namely by conducting tests in the laboratory, and the literature method, namely the method of collecting, identifying, processing written data and the work method that can be carried out. In this study, there is an experimental analysis method used to determine the feasibility of materials and flattening and flattening tests, namely: 1. Sieve Analysis Testing, 2. Specific Gravity and Absorption Testing, 3. Moisture Content and Sludge Content Testing, 4. Wear Testing (Abrasion) with Los Angeles machines, 5. Flattening and Road Deflection Testing, 6. Hot Asphalt Testing with Marshall Tools.

4. DATA ANALYSIS AND DISCUSSION

4.1 Sieve Analysis Testing

The tested materials of coarse aggregate size 10-20 mm, coarse aggregate 20-30, and coarse aggregate 5-10, sand, and stone ash were taken from Quary Tapinalu. The results of the sieve analysis can be seen in the mixture of combined aggregate proportions below.

Table 1. Mixed Aggregate Proportion Composite Gradation

Ukuran saringan (mm)	inch	Batu Pecah 20-30 21%	Batu Pecah 10-20 20%	Batu Pecah 5-10 18%	Pasir 12%	Abu Batu 29%	Presentasi lolos Hasil campuran 100%	Spesifikasi
50.8	2	21.00	20.00	18.00	12.00	29.00	100.00	100
38.1	1 1/2	16.57	20.00	18.00	12.00	29.00	95.57	90-100
19.1	3/4	5.25	20.00	18.00	12.00	29.00	84.25	79-90
12.7	1/2	0.10	6.39	18.00	12.00	29.00	65.49	60-78
9.52	3/8	0.00	0.91	15.42	12.00	29.00	57.34	52-71
4.75	No. 4	0.00	0.00	4.08	12.00	29.00	45.08	34-54
2.36	No. 8	0.00	0.00	0.00	9.79	24.39	34.18	23-41
1.18	No. 16	0.00	0.00	0.00	7.14	18.25	25.39	13-30
0.6	No. 30	0.00	0.00	0.00	2.68	12.62	15.30	10-22
0.3	No. 50	0.00	0.00	0.00	1.04	8.21	9.25	6-15
0.15	No. 100	0.00	0.00	0.00	0.51	6.14	6.65	4-10
0.075	No. 200	0.00	0.00	0.00	0.39	3.40	3.80	3-7

From the table of mixed results of the combined gradation aggregate proportion, a sieve analysis graph is obtained as shown in the figure below:

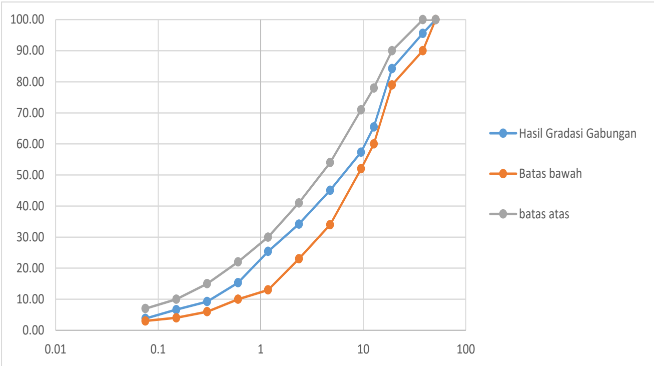

Figure 3. Combined Gradation Graph

4.2 Moisture content testing

Moisture content testing is carried out to determine the amount of water contained in the aggregate through drying

Table 2. Moisture Content Results

No	Pengujian	Hasil Pengujian	Satuan	Spesifikasi	Standar uji	Keterangan
I	Agregat kasar					
	Batu pecah 10-20 mm	1,01	%	≤ 5	SNI 1971:2011	Memenuhi
	Batu pecah 20-30 mm	0,71	%	≤ 5		Memenuhi
	Batu pecah 5-10 mm	1,01	%	≤ 5		Memenuhi
II	Agregat halus					
1	Pasir	0,15	%	≤ 1		Memenuhi
2	Abu batu	0,08	%	≤ 1		Memenuhi

4.3 Sludge content testing

This test is carried out to determine the percentage of sludge content contained in fine aggregates which aims to determine whether the aggregate is good or not for use.

Table 3. Sludge Rate Results

No	Pengujian	Hasil Pengujian	Satuan	Spesifikasi	Standar uji	Keterangan
I	Agregat kasar				SNI 1971:2011	
	Batu pecah 10-20 mm	0,72	%	≤ 1		Memenuhi
	Batu pecah 20-30 mm	0,64	%	≤ 1		Memenuhi
	Batu pecah 5-10 mm	0,03	%	≤ 1		Memenuhi
II	Agregat halus					
1	Pasir	1,86	%	≤ 5		Memenuhi
2	Abu batu	4,93	%	≤ 5		Memenuhi

4.4 Wear (Abrasion) Testing with Los Angeles Machinery

This inspection aims to determine the resistance of the coarse aggregate to wear by using the los angeles machine. With Specification ≥ 40%

Table 4. Wear Results (Abrasion)

Saringan Lolos	Saringan Tertahan	Hasil Pengujian	Satuan
¾”	1/2”	2500	kg
½”	3/8”	2500	kg
Jumlah berat (a)		5000	kg
Berat tertahan saringan No. 12 (a)		3230,00	kg
Keausan dengan 11 bola baja (%)		$= \frac{(a-b)}{a} x\ 100$ $= \frac{5000-3230}{5000} x100$ = 35,40	%

4.5 Flat and Flattening Testing

This check is intended to determine the flatness index of the coarse aggregate. With a specification of ≥10%.

Table 5. Flat and Oval Test Results

Ukuran Saringan	Berat Tertahan	% Tertahan	Lolos Kepipihan (gram)	Lolos Kelonjongan (gram)
1/5”	-	-	-	-
1	568,75	19,19	496	-
¾	1035,38	44,05	1025	-
1/2	770,8	26,01	661	397,19
3/8	318,44	10,75	377	388,66
Jumlah	M1 = 2963,37	100	M3F= 2532	M3E=785,85
Indeks Kepipihan		0,85%		
Indeks Kelonjongan		0,26%		

4.6 Asphalt

In this study, asphalt data which is secondary data is used and is data obtained from test results, which meet the specifications of Bina Marga 2018.

Table 6. Asphalt Inspection Recap

No	Jenis Pemeriksaan	Prosedur	Hasil Pengujian	Spesifikasi
1	Berat Jenis Aspal	SNI 06-2441-1991	1.0287	≥ 1,00 gr/ml
2	Penetrasi pada 25°C (0,1mm)	SNI 06-2456-1991	66,40	60-70
3	Daktilitas pada 25°C (cm)	SNI 06-2433-1991	150	≥ 100 cm
4	Titik nyala(°C)	SNI 06-2434-1991	329,0	≥ 232°C
5	Titik lembek(°C)	SNI 06-2432-1991	50	≥ 48 °C

4.7 Mashall Test Result Parameters

The analysis of marshall data is based on Bina Marga standards, where for AC-Base mixtures, the marshall parameters that are recommended to be met in determining the optimum asphalt content are stability, fatigue (*Flow*), Marshall Quotient (MQ), VIM, VMA, and VFB.

4.7.1 Stability

Stability on a pavement refers to its ability to deform due to traffic loads. The stability value in the variation of asphalt content used meets the minimum limit of the stability value specified in the 2018 Bina Marga specification for AC-Base, which is min.1800 kg.

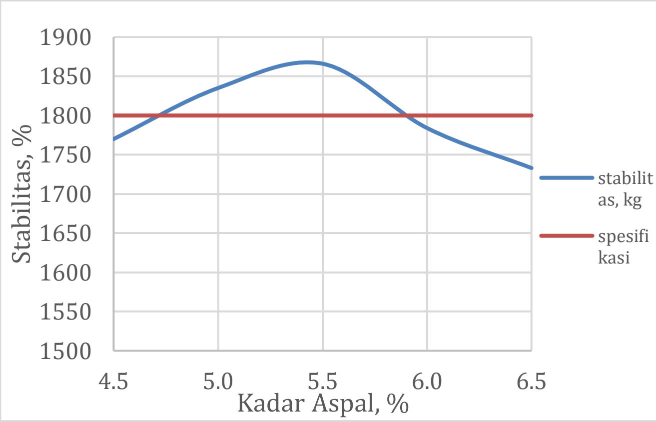

Figure 4. Graph of Stability and Asphalt Content Relationship

4.7.2 Fatigue (*Flow*)

Fatigue expresses the decrease that occurs on the pavement due to the traffic load. The fatigue value in the variation of asphalt content used meets the 2018 Bina Marga specification for AC-Base which is determined with a minimum value of 3.0 mm and a maximum value of 6.0 mm.

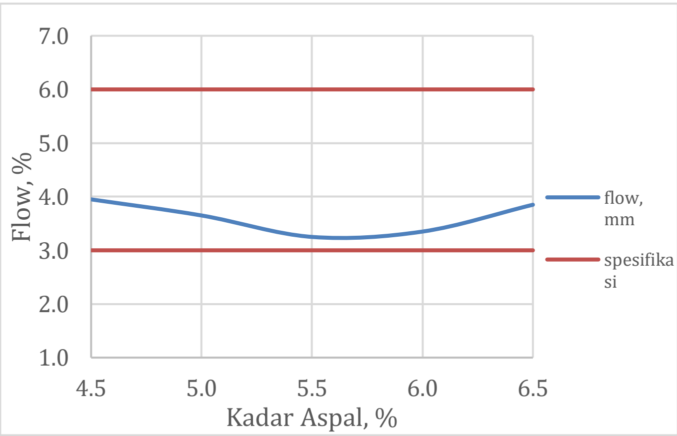

Figure 5. Graph of Flow and Asphalt Rate Relationship

4.7.3 Marshall Quotient (MQ)

Indicates the level of stiffness of a mixture if the Marshall Quotient value is too high, the mixture will become stiff and prone to cracking. On the other hand, if the Marshall Quotient value is too low, the pavement becomes too pliable and less stable.

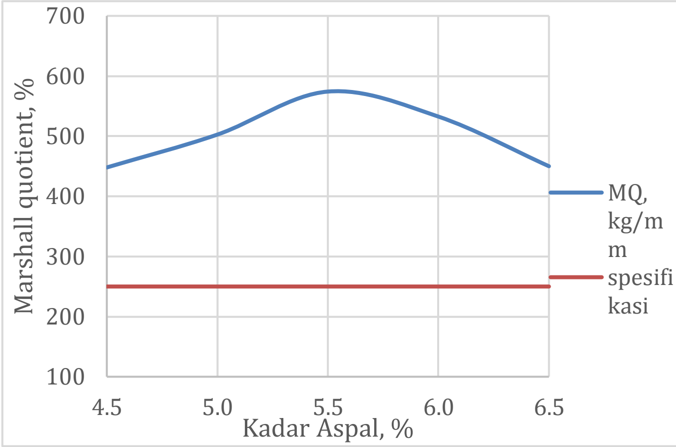

Figure 6. Graph of the Relationship of MQ and Asphalt Rate

4.7.4 VIM *(Void in Mix)*

VIM is the value of the percentage of cavities in the mixture that shows the extent of the cavities in it. In accordance with the specifications of Bina Marga 2018, cavities in the mixture are hinted at 3.0% to 5.0%.

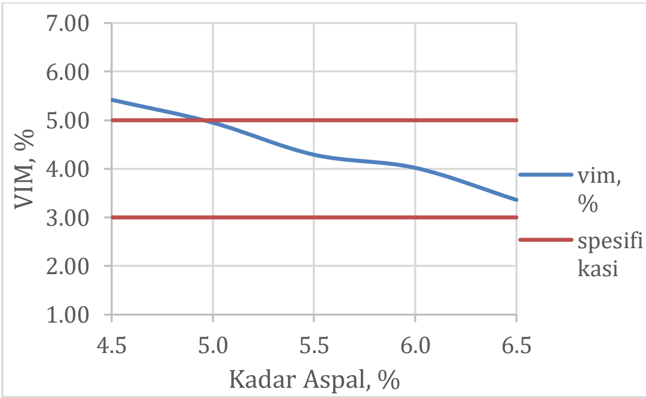

Figure 7. VIM Relationship Graph and Asphalt Rates

4.7.5 VMA (Void Minerale Aggregate)

VMA is a value that shows the percentage of air cavities between aggregate grains in a solid asphalt aggregate mixture including the effective asphalt content cavity. In accordance with the specifications of Bina Marga 2018, the cavity in the mixture is indicated to be Min.13%.

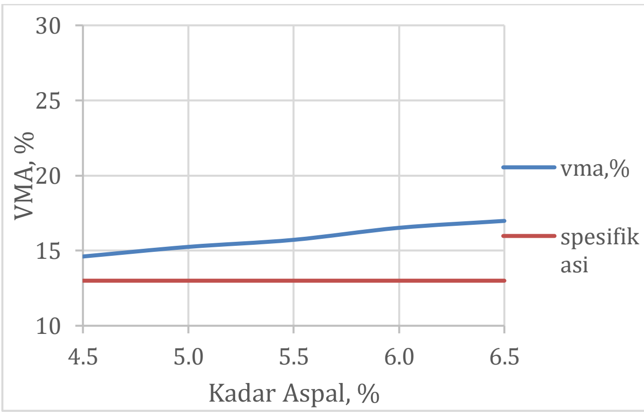

Figure 8. VMA Relationship Graph and Asphalt Rates

4.7.6 VFB (*Void Filled Bitumen*)

VFB is a value that shows the percentage of mixed cavities filled by asphalt. The VFB value meets the provisions of the 2018 Bina Marga specification with a minimum requirement of 65%.

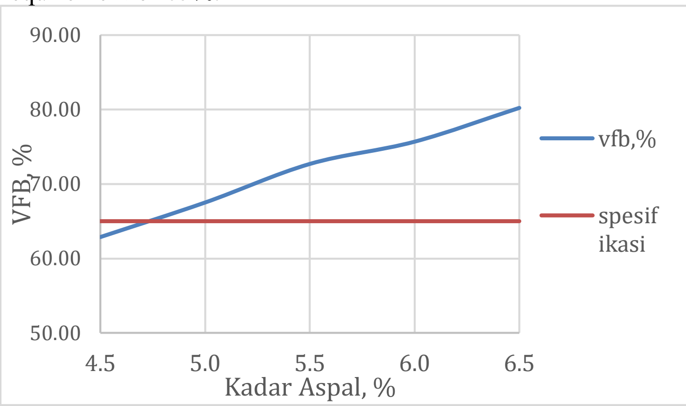

Figure 9. Relationship of VFB and Asphalt Rate

4.8 Determination of Optimal Asphalt Rate

In this study, asphalt content starting from 4.5%, 5.0%, 5.5%, 6.0%, 6.5% was used to find the optimum level in the concrete asphalt mixture (AC-Base). The optimum asphalt content is determined by referring to the Bina Marga standard which requires meeting 6 parameters, namely: Stability, Fatigue (*Flow*), *Marshall Quotient* (MQ), VIM, VMA, VFB.

Table 6. Summary of Determination of Optimal Asphalt Rate

Parameter Marshall	Kadar Aspal					Persyarataan	Ket
	4,5	5,0	5,5	6,0	6,5		
VIM	5,42	4,95	4,29	4,02	3,36	3-5	Memenuhi
VMA	14,61	15,25	15,72	16,52	16,98	Min. 13	Memenuhi
VFB	62,87	67,51	72,69	75,68	80,22	Min. 65	Memenuhi
Flow (mm)	3,95	3,65	3,25	3,35	3,85	3-6	Memenuhi
Stabilitas (Kg)	1770	1835	1866	1784	1733	Min. 1800	Memenuhi
MQ	447,97	502,60	574,15	532.54	450,00	Min 250	Memenuhi

Stability Value, Flow, MQ ,VMA ,VIM, VFB, all variations in asphalt content meet the requirements of the 2018 Bina Marga specification. Diagram of determining the optimum asphalt content of AC-Base using the marshall method

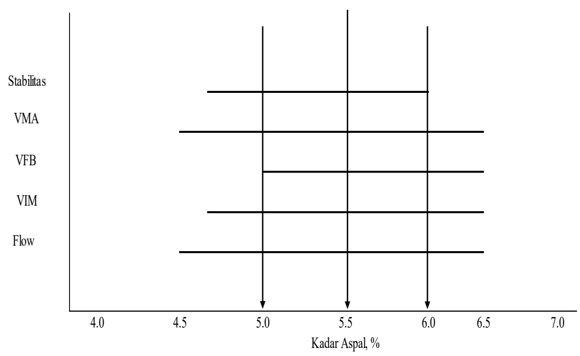

Figure 10. Optimal Asphalt Rate (KAO) Diagram

The diagram for determining the optimum asphalt content (KAO) obtained from the asphalt content range between 5.0% to 6.0% meets the requirements set for VIM, VMA, VFB, Stability, flow, and MQ values. To determine the KAO is carried out by taking the middle value of the asphalt content range, which is 5.5%, the 2018 Highway Specification, Minimum 4% and Maximum 7%.

5. CONCLUSION

The conclusion that can be presented from the results of this study based on the purpose of the study is that the Tapinalu Quary Material is suitable to be used as an aggregate of AC-Base mixture in road work, because:

Wear testing (Abrasion) with los angeles engine of 35.40% ≤ 40%

The marshall test showed that the marshall parameter values produced met the specification, namely VIM (3-5 %), VMA (Min. 13 %), VFB (Min. 65 %), Stability (Min. 1800 kg), Flow (3-6 mm), MQ (Min. 250 kg/mm).

The optimum rate for laston AC-Base mixture used coarse aggregate from 10-20 (20,%), 20-30 (21%), 5-10 (18%), sand (12%) and rock ash (29%), which obtained an optimum asphalt content value of 5.5%.

The flatness and flatness index in the coarse aggregate was obtained: The flatness index value was 0.85% ≤ 10% and the flatness index value was 0.26%≤ 10%, meeting SNI 8287:2016.

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NOMENCLATURE

Sd Dry Specific Gravity (%)
Sa Apparent Specific Gravity (%)
Sw Absorption (%)
A Oven dry specimen weight (grams)
B Surface dry saturated specimen weight (grams)
C Weight of the test piece in water (grams)
Bk Dry sand weight (grams)
B Weight of picnometer + water (grams)
SSD Surface dry sand weight (grams)
a Weight of the retest specimen (grams)
b The weight of the test piece is held in the filter No.12 (grams).
F Average value of flat aggregate granules (%)
E Average value of oblong aggregate grains (%)
FE Average value of flat aggregate granules and oval aggregates (%)
VMA Air cavities in aggregate minerals (%)
Gmb Specific Gravity of mixture after compaction (gr/cc)
Gsb Specific gravity of bulk aggregate (grams)
Ps Aggregate content, percent to total weight of the mixture (%)
VIM Cavity of the mixture after compaction (%)
B.J.Teo Maximum specific gravity of the mixture after compaction (g/cc)
VFB Asphalt filled air cavity(%)
VMA Air cavities in aggregate minerals (%)
VIM Air cavity in the mixture after compaction (%)